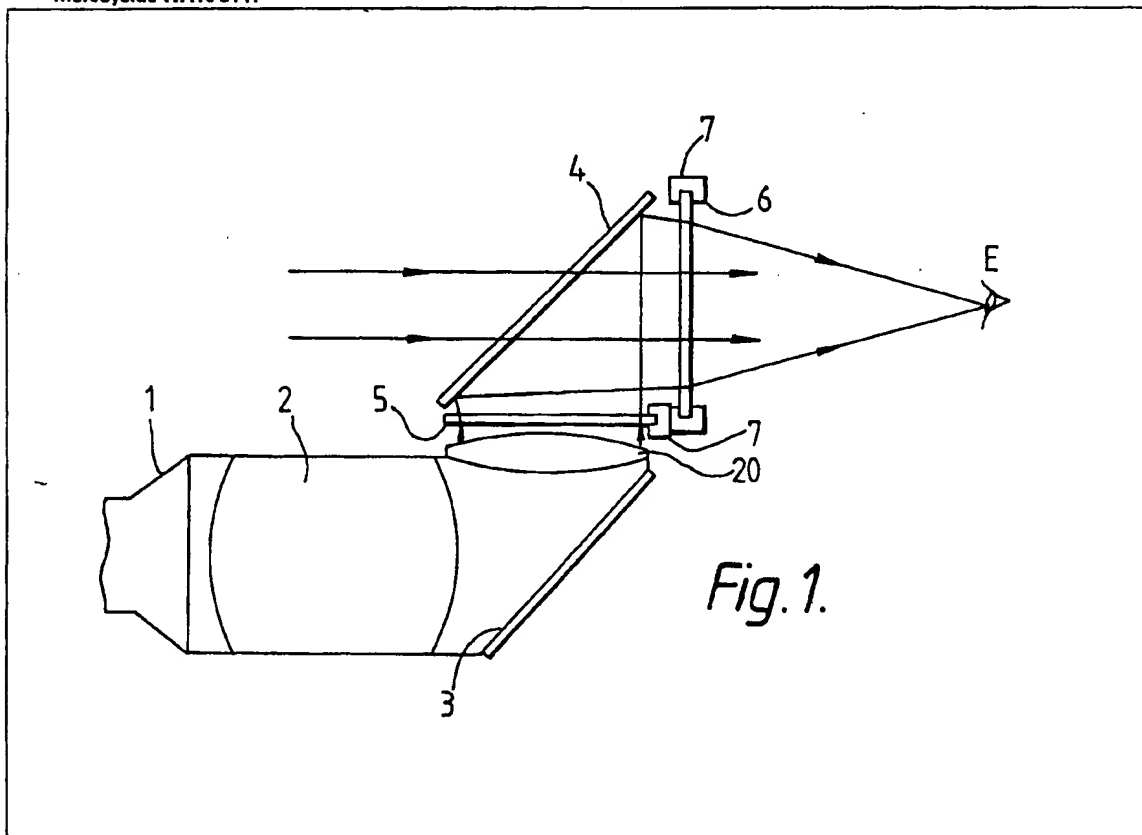


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(71) Applicants  
Pilkington P. E. Limited,  
(United Kingdom),  
Prescot Road,  
St. Helens,  
Merseyside WA10 3TT.  
(72) Inventors  
David William Swift  
(74) Agent and/or Address for  
Service  
R.A. Bride,  
Pilkington Brothers  
P.L.C.,  
Group Patents Dept,  
Prescott Road,  
St. Helens,  
Merseyside WA10 3TT.

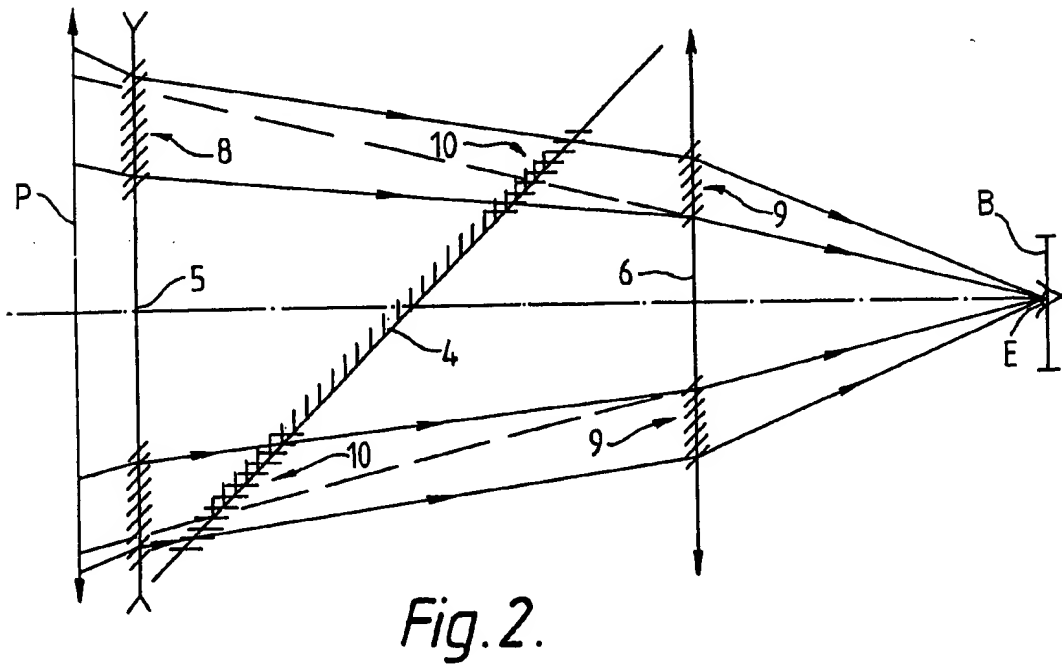
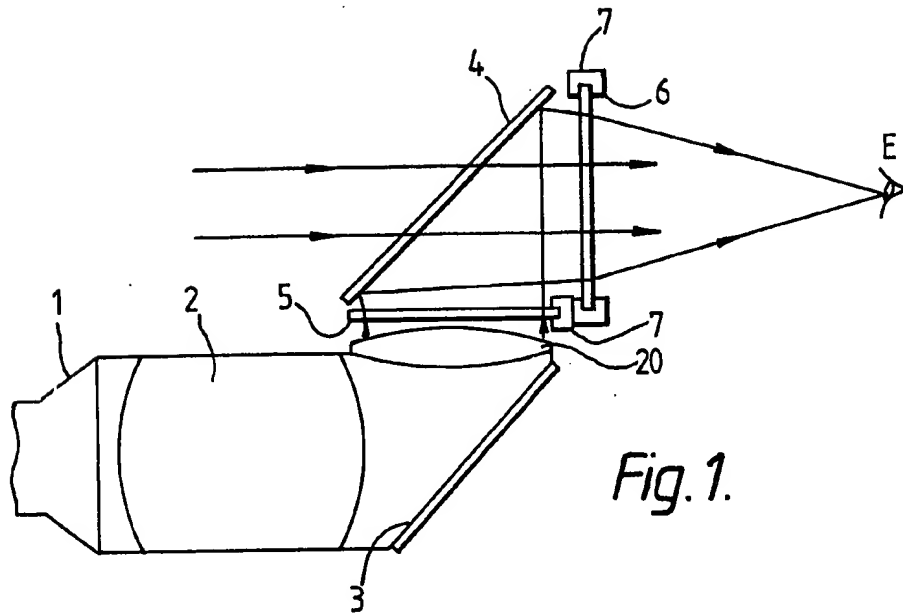
(64) Improvements in or relating to  
head-up displays

(67) To increase the field of view of a head-up display, a holographic element (5) of negative lens power is disposed between the combiner (4) and the collimating lens system (2) in front of the display source (1), and a holographic element (7) of positive lens power is disposed between the combiner (4) and the observer (E). The holographic elements (5 and 7) provide a reverse Galilean telescope preferably of unity magnification. The combiner (4) may also be holographic.



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## SPECIFICATION

## Improvements in or relating to head-up displays

- 5 This invention concerns improvements in or relating to head-up displays.

Head-up displays are used primarily in aircraft but can be employed in other vehicles or elsewhere. With a head-up display an observer (usually an aircraft pilot) views an outside scene through a combiner by which a display of information is superimposed on his view of the outside scene. Usually the combiner takes the form of a partial reflector which reflects light from the display to the observer who views the outside scene by way of light transmitted through the combiner. Normally there is a lens system between the display source and the combiner for the purpose of magnifying, and usually collimating light from, the display so as to present to the observer a magnified image at infinity.

There is a continual requirement with head-up displays for an increased field of view. Examples of proposals for increasing the field of view can be found in British Patent Specifications 1,594,648, 2006981A, and 2076178A.

According to the present invention there is provided head-up display apparatus comprising a combiner by which visual information displayed on a display source is superimposed on an observer's view through the combiner, a holographic element of negative lens power disposed in the light path from the display source to the combiner, and a holographic element of positive lens power disposed in the light path from the combiner to the observer. The holographic elements respectively of negative and positive lens power together provide a Galilean telescope arranged in reverse fashion (i.e. with the negative power element towards the object) which has the effect of increasing the instantaneous field of view. Preferably the holographic elements are such as to provide a Galilean afocal telescope of unity magnification.

The apparatus will usually include a lens system disposed between the display source and the combiner, and the holographic element of negative lens power is then preferably disposed in the light path between the outlet element of the lens system and the combiner.

Preferably the combiner also comprises a hologram.

The holograms of the holographic elements (and, when provided, of the combiner) need not cover the entire area of the substrates on which they are formed but can be provided only on that part where the display would not be visible otherwise. In particular, the holograms may be of an annular configuration round the area of light passage which provides the normal field of view of the display.

In order that the invention may be better understood an embodiment thereof will now be described, by way of example, with reference to the accompanying drawings, in which:-

Figure 1 is a schematic representation of a head-up display apparatus, and

Figure 2 is a diagrammatic representation of the

passage of light through the apparatus of Figure 1.

Referring initially to Figure 1, the head-up display apparatus comprises a display source 1 which is usually in the form of a cathode ray tube on whose phosphor the visual information is displayed. The phosphor emits light over a relatively narrow spectral band. Light from the display source is transmitted through a lens system 2 which incorporates a bending prism or mirror 3 by which the light path is turned through a right angle to the outlet lens element 20. The lens system 2 serves to magnify and collimate so as to produce a magnified image of the visual information displayed on the source 1, which image is located at infinity by reason of the collimation.

The apparatus further comprises a combiner 4 by which light from the display emerging from the lens system 2 is reflected towards the observer whose design eye position is represented at E. The observer also views the outside scene by way of light transmitted through the combiner 4. The combiner 4 is adapted to have wavelength selective reflectivity matched to the narrow wavelength range of light emitted by the display source 1. Thus the combiner 4 predominantly reflects towards the observer's eye position light of wavelengths within the range emitted by the display source 1 (thus enabling the observer to see the display image) but predominantly transmits light of other wavelengths by means of which the observer sees the outside scene.

In accordance with the invention there is provided in the light path between the outlet lens element 20 of the lens system 2 and the combiner 4 a holographic element 5 which has negative lens power, and in the light path between the combiner 4 and the observer's design eye position E a further holographic element 6 which has positive lens power. The holographic elements 5 and 6 are supported in their respective positions by suitable mounting devices 7, it being understood that the holographic elements can be relatively thin and of light weight. The holographic elements 5 and 6 may in particular each consist of a laminate having a film of suitable material in which the hologram is formed sandwiched between thin glass plates.

The holographic elements 5 and 6 respectively of negative and positive lens power provide a reverse Galilean telescope (i.e. having its negative element towards the object and its positive element towards the observer) which is effective to increase the observer's instantaneous field of view in a manner illustrated in Figure 2. For the sake of clarity and convenience Figure 2 illustrates the light travel in "straight-through" form, i.e. light is shown as being incident from the left on the combiner 4 and being transmitted therethrough to the right, whereas in practice the light is incident upwardly from below on the combiner 4 and is reflected thereby to the right.

Figure 2 diagrammatically shows the "porthole" P (which is effectively determined by the exit pupil of the lens system 2) through which light from the display emerges. Such light is received by the holographic element 5 which comprises a transmission hologram of negative lens power and therefore has a diverging effect on light rays transmitted

through it. After the combiner 4 the light is received by the holographic element 6 which comprises a transmission hologram of positive lens power and therefore has a converging effect on the light rays transmitted through it. These rays pass to the observer's eye E and the overall effect is (as known *per se* with a reverse Galilean telescope) that the porthole P appears nearer to the observer's eye, and the instantaneous field of view is therefore correspondingly increased.

The powers and dispositions of the holographic elements 5 and 6 are preferably such that they provide an afocal Galilean telescope of unity magnification. In this case the display image seen by the observer through the action of the holographic elements 5 and 6 is the same size as the display image which the observer would see "directly" by way of light transmitted without deviation by the holographic elements 5 and 6. Thus, if (as would normally be the case in practice) the holograms are of less than 100% efficiency, the display image viewed "directly" will coincide with and be of the same size as the display image viewed via the holographic lens action. It will be appreciated that the holograms need not then cover the entire area of the substrates on which they are formed. Thus the holograms of the elements 5 and 6 may be of annular configuration such that they lie round the outer part of the "direct" view light path area which provides the normal field of view of the display (i.e. the field of view there would be without the holograms). As shown by the hatched areas in Figure 2, the annular hologram 8 of the element 5 (of negative lens power) lies at the outer part of the "direct" view area while the annular hologram 9 of the element 6 (of positive lens power) effectively surrounds the "direct" view area. The holograms are disposed to ensure a complete field of view, i.e. so that there is no gap between the normal field of view and the enlargement provided by the holograms. Further, the effective area of the holograms is in practice preferably such as to accommodate viewing from any eye position within an eye box B (rather than from a single nominal design eye position).

It will be understood that chromatic aberration which would be introduced by a single hologram can be compensated, at least partially, by the other hologram so that the action of the two holographic elements 5 and 6 together may keep chromatic aberration to an acceptable level. They are desirably "thick" holograms which operate only over a narrow spectral band coincident with that emitted by the display source 1. Preferably, however, the combiner 4 is also holographic and comprises a "thick" hologram which reflects the light of wavelengths emitted by the display source 1 at the relevant angles of incidence on the combiner. It will be appreciated that the observer can view the outside scene by way of light of other wavelengths transmitted through the combiner 4 and through the holographic element 6. Where the holograms of the elements 5 and 6 are of annular configuration, the combiner 4 may have a hologram of corresponding annular configuration round the area of "direct" vision. Such annular hologram on the combiner 4 is

Indicated by hatching 10 in Figure 2 which shows its areas of overlap with the outer part of the "direct" view reflective area (indicated by hatching of opposite slope on one side only). The "direct" reflector may be provided by a conventional dichroic coating or may itself be a hologram with the annular hologram 10 superimposed thereon.

The holograms are made using light sources at their respective pupils, as distinct from in their object and image planes, and this can introduce spherical aberration. However, such spherical aberration can be compensated by appropriate corrective measures in the design of the lens system 2. Thus, while holographic elements 5 and 6 may be added to an existing head-up display apparatus, preferably the whole apparatus is optically designed as an optimised unit.

#### CLAIMS (Filed on 26/6/83)

1. Head-up display apparatus comprising a combiner by which visual information displayed on a display source is superimposed on an observer's view through the combiner, a holographic element of negative lens power disposed in the light path from the display source to the combiner, and a holographic element of positive lens power disposed in the light path from the combiner to the observer.
2. Apparatus according to Claim 1 in which the holographic elements are such as to provide a Galilean afocal telescope of unity magnification.
3. Apparatus according to Claim 1 or Claim 2 including a lens system disposed between the display source and the combiner, and having the holographic element of negative lens power disposed in the light path between the outlet element of the lens system and the combiner.
4. Apparatus according to any preceding claim in which the combiner also comprises a hologram.
5. Apparatus according to any preceding claim in which the holograms are provided only on that part of the substrates on which they are formed where the display would not be visible otherwise.
6. Apparatus according to Claim 5 in which the holograms are of annular configuration round the area of light passage which provides the normal field of view of the display.
7. Head-up display apparatus substantially as described herein with reference to the accompanying drawings.

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